King County

DRAFT

OVERVIEW OF BEST AVAILABLE SCIENCE FOR CRITICAL AREAS PROTECTION IN KING COUNTY

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King County Department of Natural Resources and Parks, Department of Development and Environmental Services and Department of Transportation

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Summary

This document provides an initial overview of scientific literature consulted in the development of King County's Critical Areas Ordinance. This overview does not fulfill King County's responsibilities to include best available science in its policies and development regulations under the Growth Management Act, but introduces more detailed analyses of best available science that will be released to the public in January of 2003.

Significant advances in natural resource sciences and management have been made in recent years, including a shift from species- and habitat-specific management to process- or systems-based management. These advances in knowledge recognize that critical areas are variable and dynamic, and exist in the landscape because of integrated ecological processes.

This overview defines each critical area, describes its functions, and provides a preliminary summary of protection mechanisms suggested by scientific literature. The areas discussed in this paper include:

- Wetlands;
- Fish And Wildlife Habitat Conservation Areas (including aquatic and terrestrial areas);
- Flood Hazard Areas;
- Channel Migration Zones; and
- Geologically Hazardous Areas.

1. Scientific Framework for Considering Best Available Science

King County's scientific framework is guided by the principles of conservation, context, connectivity and complexity. These are organizing principles for the scientific framework, and set the stage for considering best available science for critical areas.

Conservation. The act of protecting, recovering and managing an ecosystem, habitat, biological community, or species for its ecological, scientific, economic, or cultural value. Conservation encompasses actions taken to protect ecosystems, habitats and fish and wildlife species from further harm, and actions taken to preserve future options for recovery. In the face of uncertainty about the workings of ecosystems and the effects of human actions, the potential for harm should be anticipated and human actions should err on the side of caution. However, in this precautionary context, absence of adequate scientific data should not be used to justify a delay in taking conservation actions.

The scientific framework for conservation has changed dramatically over the last decades. Historically, the prevailing scientific view focussed on habitat and species as the central units of conservation, and viewed nature as stable and in equilibrium. This view is neatly summed up in the phrase "the balance of nature" that is so much a part of discussions about the natural world. However, observations of natural systems over the last three or four decades have questioned these ideas. Generally, the view of nature that has emerged is one of change at many scales of time and space and of non-equilibrium. It is this dynamic and variable state of nature that results in diversified and healthy ecosystems and biological communities. Environments are best and most efficiently maintained and restored if this dynamic characteristic is incorporated into their management. Moreover, because change occurs over long time periods and large areas, natural resource management must include a more comprehensive context of analysis for resource protection.

Biological diversity, often referred to as biodiversity, is the basis for healthy environments. By protecting biodiversity, healthy and functioning ecosystems can be maintained and restored. Incorporating best available science into County environmental regulations will influence natural resource protection, restoration, and conservation. Current scientific literature emphasizes several principles of natural systems that were not explained by the more static or classical view of nature. These principles, the Three Cs (context, connectivity, complexity), are described below.

Context. All natural resource protection occurs within an ecologically defined context. The watershed is such a context, and is an appropriate scale for planning. A systems approach to the watershed conservation includes consideration of how all of the components of a site function together within the site and surrounding land uses. The arrangement of habitats and ecosystems across the watershed shapes local conditions and responses. Local changes, in turn, have broad-scale impacts over the landscape. Therefore, it is critical to examine context both at the site-specific and the larger scale. Humans, fish, and wildlife are embedded in this context.

Connectivity. Natural systems are open to the movement of materials, and energy including species from outside the system; exchanges with other systems are common. An ecosystem's structure and dynamics are influenced by adjacent habitats and ecosystems. This linkage of one system to another is called connectivity. To protect or restore connectivity, human intervention in the ecosystem should follow this hierarchy:

- Maintain and restore the magnitude and rates of natural processes—both physical and biological (e.g., hydrology, sedimentation, beach erosion and channel migration as examples of physical processes, and plant succession, wildlife reproduction cycles, and source-sink dynamics as biological processes);
- Maintain and restore structural complexity (e.g., hydraulic and biological diversity);
- Maintain and restore function (e.g., soils permeability, plant evapotranspiration, fish or amphibian spawning, rearing, migration and refuge); and
- Maintain and restore particular ecosystem attributes, habitats (e.g., pools, spawning riffles, nest tree), and critical species (e.g., chinook salmon, bull trout, western toad, red-legged frog, and native freshwater mussels).

This principle directs human intervention to follow the ecological heirarchy of first identifying and restoring process, then structure, then function. Only where actions to address this heirarchy fail, or are not feasible, should actions be taken to maintain and restore particular ecosystem attributes, habitats and critical species. The presumption is that at the fourth level of the heirarchy actions are unsustainable in the long-term.

Ecosystems and habitats suitable for particular species are the outcome of various geologic, hydrologic, and biologic processes acting on structural characteristics of the system over time and space. These processes must be maintained at their natural rates and locations for ecosystems to be sustainable and for habitats and their species to be maintained. In general, the more variation from basic processes, the greater the severity and longevity of effects.

Complexity. As natural systems mature and evolve, the resultant structural patterns and linkages among the physical, chemical, and biological elements of a system become evermore complex. The extent of and degree of this complexity is formed and driven by the changing patterns that systems undergo through time and the processes controlling those patterns. These patterns contribute to productivity, diversity, richness, and sustainability and thus are critical characteristics of a system. The contemporary view of ecology emphasizes these processes and the behavior of systems rather than static endpoints or stability.

2. Discussion of Critical Areas Literature

A. Wetlands

What Are Wetlands?

Wetlands are legally defined in federal, state, and local regulations generally as those areas that are inundated by surface or ground water with a frequency sufficient to support plants and animals that depend on saturated or seasonally saturated soil conditions for growth and reproduction. From a biologic perspective, wetlands occur in the landscape because of the combination of water, soils, and plants that form unique communities. The presence of water influences both the soil chemistry and plant communities that live in these areas. There are many different kinds of wetlands, from those dominated by open water areas, to forested wetland areas in which standing water is rarely present at the surface for an extended length of time. Common names for wetlands are ponds, bogs, fens, marshes, wet meadows, shrub swamps, and wooded swamps, and each of these has a unique set of attributes. Bogs and fens in King County are rare and unique wetland types that were formed in closed depressional systems following glaciation.

A common wetland classification system was developed by the U.S. Fish and Wildlife Service to classify wetlands based on dominant vegetation communities (where dominant is defined as 30 percent or greater). This classification system refers to wetlands and their habitats as forested, scrub-shrub, emergent, or open water. In addition, wetlands can be either freshwater-dependent (e.g., palustrine, lacustrine) or saltwater-dependent (e.g., estuarine wetlands). The majority of remaining wetlands in King County are freshwater depressional systems classified as palustrine. A second popular method of classifying wetlands, developed by the U.S. Army Corps of Engineers is by hydrogeomorphic characteristics, namely wetlands that function similarly because of identical geomorphic settings such as riverine, depressional and slope conditions. The majority of remaining wetlands in King County are freshwater palustrine depressional outflow wetlands.

How Do Wetlands Function?

Wetlands perform a number of different functions. The most commonly cited wetland functions are related to water quality (e.g., biofiltration, sediment trapping, erosion control, aquifer recharge), water quantity (flood storage and retention, base flow support, groundwater discharge/recharge), and wildlife habitat (amphibians, birds, fish and mammals for all or portions of their life cycles).

The functions that wetlands provide are partially dependent upon the geographic context, or watershed position, within which the wetland is located. For example, headwater wetlands often provide base flow support to stream systems, holding and storing water throughout the year. Estuarine wetlands provide important rearing habitat to juvenile chinook salmon and other fish and wildlife species whereas isolated depressional and semi-permanently flooded wetlands generally have no fish and often different wildlife. Riverine wetlands may provide important rearing and refuge areas for salmonids and other fish and wildlife species.

Over the last decade several wetland function assessment methods have been developed. Wetland function assessment methods are used as tools to measure the extent to which a wetland is capable of performing specific functions. Function assessment methods do not directly measure function; rather, they rely on structural indicators (such as vegetation type, maturity, and degree of vegetation interspersion) as surrogates of function. For example, the presence of mature trees (based on diameter), and type of tree (conifer vs. deciduous) may be used as an indicator of habitat available for cavity nesting birds.

How Should Wetlands Be Protected?

The most common method for wetland protection is by the use of fixed buffers, whose purpose is to protect wetlands from disturbance and other detrimental impacts from the immediately adjacent existing or expected land use. A wide range of buffer widths are recommended or required by regulatory agencies. An even greater range of buffer widths are identified in research studies for the protection of aquatic areas and wildlife.

Table 1 presents a review of the literature on wetland buffers as they relate to protection of wetland functions related to physical and chemical functions. The table demonstrates that the ability of buffers to protect these functions is dependent on wetland classification (i.e., characteristics).

Table 1. Depressional Wetlands Hydrology and Water Quality Buffers

Wetland Functions	**Hydrogeomorphic class: Depressional Closed**		**Hydrogeomorphic class: Depressional Outflow**	
	Width in Feet of Experimental Reductions Measured	**Vegetation**	**Width**	**Vegetation**
Hydrology & Related Functions				
(Reducing Peak Flows) Specific attributes of Peak Flow are • Magnitude • rate of change • velocity • frequency • duration • Timing (Seasonality) • Depth	Undetermined	Complex structure of herbs, shrubs and trees is best.	The wider the better but not necessarily as wide as with depressional closed wetland.	Complex structure of herbs, shrubs and trees is best.
Downstream Erosion	Not applicable	Not applicable	Greater widths incrementally better	Complex structure of herbs, shrubs and trees is best.
Groundwater Recharge	Greater widths incrementally better.	Complex structure of herbs, shrubs and trees is best.	Greater widths incrementally better	Complex structure of herbs, shrubs and trees is best.

Wetland Functions	Hydrogeomorphic class: Depressional Closed		Hydrogeomorphic class: Depressional Outflow	
	Width in Feet of Experimental Reductions Measured	**Vegetation**	**Width**	**Vegetation**
Wetland Recharge	Greater widths incrementally better.	Complex structure of herbs, shrubs and trees is best.	Greater widths incrementally better	Complex structure of herbs, shrubs and trees is best.
Water Quality Enhancement				
• Water temperature	82 for an assumed 100% attenuation	Forest	Same as for Depressional Closed Wetlands	
	100 for 99.9 %	Forest		
	10-361	Check reference		
• Sediment	200 for (80%)	Grass	Same as for Depressional Closed Wetlands	
	100 for 75-80%	Forest		
	75-375 ft	Check		
	33-197			
• Nutrients (nitrogen/nitrate, phosphorus)	85 for 78% Orthophosphorus, 76% Kedall N 2% ammonia	Grass	Same as for Depressional Closed Wetlands	
	62 for 89%N and 80%P	Forest		
	13-279	Check reference		
• Metals	13-279	Check reference	Same as for Depressional Closed Wetlands	
• Pathogens (fecal coliforms)	75 for 30 %	Grass	Same as for Depressional Closed Wetlands	
	100 for 60%	Grass		
• Herbicides	65 for 8-100%	Grass	Same as for Depressional Closed Wetlands	
	15-30 for 28-72%	Grass		
• Estrogens	60 for 98%	Grass	Same as for Depressional Closed Wetlands	
• All factors for water quality enhancement	50/15-100/30 for *effective removal*	Assumes native vegetation (Check reference)	Same as for Depressional Closed Wetlands	

Table 2 presents a literature review of wetland buffers related to wetland-dependent wildlife. Note that often wildlife is grouped together; this review separates the groups that compose wildlife types and characteristics related to wildlife habitat for clarity. Also to be noted is that only depressional wetlands are identified – buffers to protect riparian wetlands may differ.

Table 2. Wetland Buffers for the Conservation of Wetland-Dependent Wildlife

Taxa	Depressional Wetland Type		
	Width in Feet Measured for Identified % 'Impact'	**Vegetation**	**Comment**
Invertebrates	Undetermined although minimal compared to vertebrates	Undetermined	Microclimatic changes are thought to extend up to two tree lengths (distance provided) inside a forest patch (Harris 1984, Franklin and Forman 1987). Roads are known to pose a functional barrier to small-bodied ground-dwelling animals such as snails, and butterflies (Bennett 1991).

Taxa	Depressional Wetland Type		
	Width in Feet Measured for Identified % 'Impact'	**Vegetation**	**Comment**
Amphibians	3,281 for ˜ 99%	Forest	Based on amphibian dispersal (Richter's 1997 extensive review of existing amphibian literature).
	1,600 for ˜ 85% 1,000 for ˜ 75%	Forest	Based on extrapolation from dispersal curve (Richter's review of literature).
	1,968 for 83%	Native Vegetation	(Dodd 1996)
	538 for 95%	Native Vegetation	Salamanders only (Semlitsch 1998).
	328 for undetermined % dispersal 984 for ˜ 100%	Forest Forest	Removal of forest cover as far as 328 ft. (100-m) away from breeding ponds can affect amphibian dispersal movements (Raymond and Hardy 199l), that for many species span a distance of at least 984 ft. (300-m).
Reptiles	902 for 100% & 240 for 90%	Native Vegetation	(Burke 1995) Freshwater turtles examined in this study required a 902 ft (275m) upland buffer zone to protect 100% of the nest and hibernation sites (Burke and Whitfield 1995).
Birds	1640 for total species richness	Forests	Human avoiders decrease, exploiters increase (Richter & Azous 2001).
	394	Native Vegetation	Willow warbler successful breeding (Foppen 1994).
	min 82 for 100	Forest	For sensitive passerine species (Croonquist & Brooks 1993).
	656 for 100%	Forest	Less than 656 decreases bird habitat quality, affects breeding dispersal, and reduces population density (Föppen and Reijnen 1994, Reijnen and Föppen 1994, Reijnen et al. 1995).
Mammals	1640 for total species richness	Forest	Large woody debris in buffers significant correlate to small mammal species richness (Richter & Azous 2001).
	279-2,844	Native Vegetation	White-footed mouse dispersal (Gustafson 1994).
Herptiles, birds and vegetation	6,561 ft. (2,000 m) for vegetation, herptiles and birds	Native Vegetation	Increasing road density within this distance decreased richness of all three (Findlay and Houlahan 1997).

Other less common but more comprehensive methods of wetland protection include regulating landscape and watershed-level activities such as those recently institutionalized within recent Basin Plans. One such method identifies Regionally Significant Aquatic Resource Areas to maintain base water levels at select wetlands (Bear Creek, Issaquah Creek and Cedar River Basin and Nonpoint Action Plans) whereas a second even more inclusive method protects wetland hydrological function by minimizing clearing (i.e., vegetation removal) to less than 35 percent of subdivisions (regulation in Bear Creek and Issaquah Creek and voluntary in Cedar River Basins). Although Regionally Significant Aquatic Resource Areas also provide habitat for wetland and other wildlife, maintaining 65 percent overall watershed basin vegetation may provide a large measure of additional wetland hydrology and water quality protection as well as habitat protection for wildlife if strategically located.

Fixed buffers alone cannot protect wetlands in the long-term. However, buffer widths based on wetland function would significantly help in wetland protection and conservation. Unfortunately, most wetland buffers implemented through development regulations generally assume that a given type of wetland will support a given array of functions; this assumption homogenizes wetlands. Wetlands protected in this way are unlikely to continue to sustain such unique functions over time. Finally, static buffer protection freezes current wetland conditions (or historic conditions) rather than acknowledging that wetlands are dynamic evolving ecosystems in which both short and long-term natural processes combine to create an array of functions that change over time. Best available science stresses that ecosystems are complex, dynamic, and highly variable; conservation and protection measures should acknowledge this complexity and protect and restore natural processes, structures, and functions.

Based on the approaches outlined above, wetlands protection should not occur in piecemeal fashion. Rather, protection should occur holistically through watershed and landscape-scale planning that considers wetland resources and ecosystem integrity in the context of natural processes and potential human impacts to the landscape. In summary, watershed and landscape planning should include (1) identification of critical wetland functions for conservation, (2) identification of the processes for their continuance, and (3) conservation through a variety of appropriate measures. Such an integrated approach goes beyond individual wetlands and incorporates watershed attributes such as ecological networks, hubs, and corridors. Through this type of holistic analysis, changes throughout the watershed may be tracked and managers can begin to determine cumulative effects of their actions in a meaningful way.

B. Fish and Wildlife Habitat Conservation Areas

What Are Fish and Wildlife Habitat Conservation Areas?

Fish and Wildlife Habitat Conservation Areas (FWHCAs), as defined by the GMA, are lands that are designated and managed for maintaining targeted species within their natural geographic distribution so that isolated subpopulations are not created. Such areas are considered to be critical for the long-term viability and proliferation of certain native fish and wildlife species. GMA includes guidelines that jurisdictions must consider when designating these areas. King County's Comprehensive Plan includes policies for the protection of the following FWHCAs:

- Habitat for federal or state listed endangered, threatened or sensitive species.
- Habitat for Salmonids of Local Importance including:
    - kokanee/sockeye/red salmon,
    - chum salmon,
    - coho/silver salmon,
    - pink salmon,
    - coastal resident/searun cutthroat,
    - rainbow trout/steelhead,
    - bull trout,

    - Dolly Varden, and
    - pygmy whitefish, including juvenile feeding and migration corridors in marine waters;
- Habitat for Raptors and Herons of Local Importance: red-tailed hawk, osprey, black-crowned night heron, and great blue heron;
- Commercial and recreational shellfish areas;
- Kelp and eelgrass beds;
- Herring, sand lance and smelt spawning areas;
- Wildlife habitat networks designated by the County, and
- Riparian corridors.

Many of the species, habitats, and ecosystems that use and/or comprise the FWHCAs possess attributes that subject them to a greater risk of extinction. Priority Habitat Species (PHS – as designated by the Washington Department of Fish and Wildlife) listed species, habitats and ecosystems that are rare orendemic are less resilient to change than those not listed. Further discussion of FWHCAs is divided below by aquatic and terrestrial areas.

Aquatic Areas

What Are Aquatic Areas?

Aquatic areas are ecosystems whose processes, structure, and function are attributable to the influence of water. Aquatic habitats are the areas occupied by fish and wildlife and a host of less obvious plants and animals within freshwater and saltwater environments. Aquatic habitats arise from complex interactions of water, soil, and vegetation within rivers, streams, lakes, ponds, wetlands[1], estuaries, marine nearshore areas, and shallow aquifers (hyporheic areas) in King County. They can be calm like a large lake or fast moving like a small stream or river at flood, and they can be fresh, brackish, or salty. In addition to being a place for plants and animals to reproduce, rear, migrate, and obtain food and water, they are a source of many other valuable functions including flood control, water supply, water quality purification, recreation, and shipping and conveyance of stormwater runoff. This discussion focuses primarily on stream and riparian areas that influence the structure and function of the aquatic community in a stream, and particular consideration is given to salmonids. Wetlands are discussed separately (above).

How Do Aquatic Areas Function?

Ultimately the function of aquatic areas is the transport of water, whether rushing down a stream or as tides in Puget Sound that generates the energy necessary to form aquatic habitats. The types and amounts of aquatic habitats reflect a complex interplay of water energy acting upon soil and vegetation and the fish and wildlife that use them. These processes occur over time and space.

As recent as ten to fifteen thousand years ago (recent in geologic time), glaciers set the stage for the landscape today. They left a relatively fresh, erodible landscape with complex and dynamic features such as Puget Sound's eroding bluffs, meandering rivers, unstable valley hillsides, and steep ravines, as well as less dynamic features like lakes, ponds, bogs, and fens.

[1] The proposed King County critical areas ordinance discusses and defines wetlands separately from other aquatic areas, since wetlands are regulated under different statutes and legal mandates.

Following glaciation, some of the largest trees and highest biomass of vegetation of any ecosystem on earth became established in the coastal areas of the Pacific Northwest (including Puget Sound). This vegetation helped to stabilize soils and stream channels. It also moderated the post-glacial hydrology (spring and storm runoff, winter and summer baseflows, and groundwater dynamics) to which aquatic-oriented plants and animals adapted. The canopy, understory, and accumulated organic matter of those forests intercepted and stored the vast majority of storm precipitation and subsequently metered it out gradually to aquatic habitats. This system of capture and gradual release tempered the otherwise high and low extremes of the hydrologic cycle.

Forest vegetation helps create structurally diverse aquatic habitat and is important in nutrient storage and cycling. Woody debris, both large (such as whole trees) and small (leaves and branches), accumulates, sometimes in huge quantities, in streambeds and estuaries and along lake and marine shorelines. In aquatic areas, fallen woody debris breaks up the flow of water and sediment and directs the force of flowing water to create a more complex mix of pools and riffles that would not otherwise occur from rocks alone. These pools and riffles provide habitats for migration, spawning, rearing, and refuge from periodic disturbances (such as major storms or landslides). In the marine nearshore environment, woody debris helps create habitats ranging from muddy bays to gravel or bedrock beaches. Finally, vegetation serves as a source of nutrients upon which other plants and animals thrive.

Salmon and trout are of particular interest in the Puget Sound region for many cultural, social, political, biological, and aesthetic reasons. The Salmonidae family of fishes (salmon, trout, char, and whitefish) have played a great role in shaping the aquatic and terrestrial ecosystems in this region. Presumably these species exhibit high life history diversity in response to the diverse habitats available to them. Their fusiform (torpedo) shape is highly adapted to life in flowing water. Although they overlap considerably in their distribution, each species and life history form arises out of adaptations to specific aspects of the dynamic and complex aquatic habitat: some species are well-adapted to spawning in big rivers (e.g., chinook salmon) and others to smaller streams (e.g., cutthroat); some prefer rearing in very fast water (e.g., steelhead) and others in relatively slow areas such as beaver dam or backwater ponds (coho) or large lakes (sockeye). Some species gravitate toward the coldest highest elevation streams possible (bull trout), and others are found in the lowermost reaches of big rivers (pink and chum salmon).

Many salmonid species are anadromous—they spawn in freshwater, then migrate to and mature in marine waters, then ultimately return years later to their natal streams as much larger individuals and bring back nutrients from the ocean. These nutrients benefit their offspring and many other plants and animals in the otherwise low nutrient freshwater streams of Puget Sound. Salmon often spawn in such great numbers that their digging action cleans significant amounts of stream substrates as fine sands and silts are washed out of the gravel. Given their huge role in the Puget Sound region ecosystem, salmon are often called keystone species. Although they are among the most visible animals in the region, salmonids are only a small part of the species diversity found in aquatic habitats.

The species that evolved in the watersheds of King County didn't evolve under static conditions. Rather they evolved and continue to thrive best in aquatic habitats that are occasionally affected by disturbance events such as floods, fires, droughts, volcanoes, and glaciers. These natural events periodically reshape the landscape. They mix-up and transport new gravel and woody debris. They cause river channels to meander and beaches to erode. Through disturbance, they form new habitats and erase old ones. The frequency and magnitude of these events over time define a region's disturbance regime. It is to those regimes that the native species are adapted.

How Should Aquatic Areas Be Protected?

Aquatic areas are not static. They are derived from and supported by dynamic ecological processes (such as hydrologic processes, sediment routing, vegetation succession, and speciation). Protection should allow for those processes to occur at natural rates and magnitudes. Attempting to mimic natural processes through artificial means may be an option, although this approach is not sustainable, and therefore is the least likely to succeed. Planning for and allowing natural rates of change to occur is one of the keys to sustaining aquatic habitats and the species that use them. Critical to protection and long-term restoration of ecosystems is maintaining the connectivity of processes that allow water, soil, vegetation and animals to interact.

The dynamic nature of aquatic habitats notwithstanding, the most common method for aquatic habitat protection is through the use of buffers whose purpose is to protect the aquatic habitat from disturbance and other detrimental impacts. A wide range of recommended buffer widths is common among aquatic habitat studies (see Tables 3, 4 and 5; these tables are excerpted from the Biological Review Tri-County Model 4(d) Rule Response Program by Parametrix, Inc.).

None of the studies reported in these tables recommend zero buffer width, nor do those studies recommend buffers beyond the equivalent of more than several tree heights. Buffer widths of one site potential tree height (SPTH), the maximum height a tree will attain given the existing geology, soils, and other site conditions, range from 50-250 feet over 300 years in western Washington. A buffer width equal to one SPTH would be required to provide for a broad range of aquatic area functions and prevent the loss of salmonid populations.

It should be noted that riparian buffers are only one component of an effective management approach. Other approaches protect processes, structure and function from an ecosystem perspective. For example, aggressive stormwater management in the urban area, reducing soil imperviousness and restoring natural forest cover in rural areas, and other actions should also be employed to maintain aquatic functions.

Table 3. Riparian Buffer Functions and Appropriate Widths Identified by May (2000)

Function	Range of Effective Buffer Widths	Minimum Recommended	Notes On Function
Sediment Removal/Erosion Control	26 - 600 ft (8 – 183 m)	98 ft (30 m)	For 80% sediment removal
Pollutant Removal	13 - 860 ft (4 - 262 m)	98 ft (30 m)	For 80% nutrient removal
Large Woody Debris	33-328 ft (10 –100 m)	262 ft (80 m)	1 SPTH based on long-term natural levels
Water Temperature	36 - 141 ft (11 – 43 m)	98 ft (30 m)	Based on adequate shade
Wildlife Habitat	33 - 656 ft (10 – 200 m)	328 ft (100 m)	Coverage not inclusive
Microclimate[2]	148 - 656 ft (45 – 200 m)	328 ft (100 m)	Optimum long-term support

[2] Microclimate is the local climate (humidity, wind, and air temperature) within the stream-riparian ecosystem that is primarily affected by the quality and extent of riparian vegetation in a buffer.

Table 4. Riparian Functions and Appropriate Widths Identified by Knutson and Naef (1997)

Function	Range Of Effective Buffer Widths (Ft)
Water Temperature	35 - 151
Pollutant Removal	13 - 600
Large Woody Debris	100 - 200
Erosion Control	100 - 125
Wildlife Habitat	25 - 984
Sediment filtration	26 - 300
Microclimate	200 - 525

Table 5. Riparian Functions and Appropriate Widths Identified from FEMAT (1993)

Function	Number of SPTH	Equivalent (Ft) Based on SPTH of 200 Ft.
Shade	0.75	150
Microclimate	up to 3	up to 600
Large Woody Debris	1.0	200
Organic Litter	0.5	100
Sediment Control	1.0	200
Bank Stabilization	0.5	100
Wildlife Habitat	-----	98 – 600

Buffers can be fixed or variable in width. Fixed-width buffers are generally a compromise between minimizing ecological impacts to streams and minimizing economic impacts to developers and property owners. Fixed-width buffers do, however, risk failure unless conservatively designed. Salmonid conservation requires variable ecologically-based approaches for establishing buffer-widths at watershed, stream, or site scales. While variable-width buffers may be more ecologically sound and allow landowners more flexibility, information does not currently exist that provides variable width buffer recommendations. With the current knowledge of riparian systems, it is difficult to determine the exact causes of habitat function degradation because it is dependent on numerous factors in addition to riparian vegetation.

Design of riparian buffers must consider the ecological values of the resource, land-use characteristics, and existing riparian quality throughout watersheds in order to address the cumulative impacts on aquatic area functions. Appropriate buffer widths depend on the area necessary to maintain the desired riparian and aquatic area functions for the given suite of land-use activities. Human intrusions are a factor not often assessed in reviews of buffer widths. A wider buffer may be desired to protect streams from impacts resulting from ad hoc trail construction, recreation, pets, garbage, and tree removal (for goals such as view improvement or hazard reduction). These activities are associated more with areas of high-intensity land use and thus wider buffers, or restrictions that keep the potential hazard from occurring (such as building setbacks) may be needed, while narrower buffers may suffice in areas of low-intensity land-use.

Streams and other aquatic areas in high-intensity land-use areas are generally degraded, while streams in areas of low-intensity land use are generally in better condition and offer more opportunities for salmonid conservation or restoration efforts. An assumption is that in highly developed areas there is a point beyond which requiring wider buffers for the few remaining undeveloped sites is ineffective at meeting conservation goals. In this context, restoration is still possible, but would likely entail highly engineered and costly solutions. Opportunities to successfully implement these challenging solutions are expected to be low. Buffers in low-intensity land-use areas provide better protection for retaining quality habitat and existing salmonid populations than buffers in highly urbanized areas. Placing a higher priority for protecting areas that retain more recovery potential is consistent with recommendations for salmonid restoration. Buffer vegetation type, diversity, condition, and maturity are equally as important as buffer width. Generally, the best approach to providing high-quality buffers is to establish and maintain mature native vegetation communities.

Because the influence of riparian vegetation on some stream habitat functions increases as stream size decreases (e.g., control of water temperatures by shading), riparian corridor continuity is particularly important in headwater streams that make up most of the stream length within a watershed and that may contain more wetland areas. Therefore, protection of headwater areas may offer the greatest benefits to streams. Most lowland Pacific Northwest streams have fragmented riparian corridors because they flow through urbanized or agricultural areas.

Terrestrial Areas

What Are Terrestrial Areas?

Terrestrial habitat protection areas are uplands not under the direct influence of ground or surface waters that define wetlands and aquatic areas identified and discussed above. Terrestrial areas provide unique food, cover, shelter, breeding and movement habitat essential for priority species to subsist.

Numerous mammals, birds, amphibians and reptiles are identified as priority wildlife in King County (see Table 6). Each species occupies and requires specific foraging, breeding, nesting, roosting, hibernation or other living habitats in terrestrial areas. Some of these species are endemic species (or habitats or ecosystems), in other words, those that are native to, and occur only in, a particular area or locale. Endemic species generally have adapted to very specific requirements that are linked to particular habitat or ecosystems that are, themselves, rare. Endemics may be represented by only a few individuals or be confined to small, unique geographic areas. Consequently even small perturbations are likely to cause extinction of endemic species or their limited unique habitats and ecosystems.

Priority species may also be keystone species. Keystone species are generally animals that exert a disproportionally significant effect on the structure of the biological community of which they are a part. Such species often prevent dominance by a single other species and thereby maintain biodiversity in the community. Other species may act as keystones in another way. For example, over 137 vertebrate species at last count were predators or scavengers on one or more life stages of salmon in the Pacific Northwest.

Both endemic and keystone species in terrestrial areas may warrant particular consideration because of their dependence on specific environmental conditions not commonly represented in this area, or because of changing natural or anthropogenic (human-caused) circumstances that have reduced their range, abundance, or distribution.

How Do Terrestrial Areas Function?

Terrestrial FWHCAs are intended to safeguard state and federally listed species (as well as other important species) thereby maintaining native biodiversity in King County. These conservation areas provide food and cover, spawning, breeding and nesting areas, and facilitate homing, migrations and other activities for such species. At the same time, these areas protect air and water quality and provide other critical ecological functions of benefit to humans and a wide variety of biota in general. Indeed, species, habitats and ecosystems play a critical role in healthy ecosystems.

How Should Terrestrial Areas Be Protected?

There is a broad range of protection needs discussed in scientific literature for the multitude of wildlife species in King County. Table 6 lists terrestrial species called out in the King County Comprehensive Plan along with known locations within the County and relevant conservation mechanisms suggested by scientific literature. Suggested measures include protections for nest sites, roosting areas, hibernaculae and other areas of critical use, and buffers to protect identified functions.

Biologists agree on the importance of protecting actively used critical areas such as spawning sites and nesting trees. Equally recognized is the fact that such specific ecosystem and habitat attributes vary in time and space. For example, bald eagle, red-tailed hawk, pileated woodpecker and other wildlife nesting trees and snags blow down or rot with the seasons, requiring these birds to find new nesting trees and snags. Consequently, to maintain sustainable populations of these large-tree-nesting priority species, alternate nesting trees must be available for occupancy naturally or through anthropogenic actions. Likewise other indispensable habitat must be available for additional life stage requirements for survival of a species. Conservation of critical spawning and breeding habitat through buffers and other means is essential, however, it is just as important to provide adequate habitat for other crucial needs such as foraging and wintering. Conservation priorities must therefore include the protection and or restoration of the full requirement of ecosystem needs.

Conservation needs are addressed directly (through actions such as acquisition and purchase of easements) and indirectly (through innovative programs such as Regionally Significant Resource Areas protection).

See discussion of wetland-dependent wildlife protection mechanisms in the Wetlands section above.

Table 6. Priority Wildlife Species and Associated Protection Mechanisms

Species	Species Location	Protection Mechanisms Suggested by Literature
Bald Eagle	Recorded throughout King County, core habitat shown in western portion of King County. Found in Urban and Rural Environments.	<u>Nest Tree</u> • 400-foot permanent buffer around core nest tree stand. Site specific Bald Eagle Management Plan (BEMP) required for any activities proposed within buffer and which requires consultation with WDFW. • 400-800 feet retain all known perch trees and all conifers >18 inches in dbh. Also retain 50% of pre-clearing or pre-construction conifer stand with representative diameter. Season disturbance/noise limitations within buffer (Feb 1- June 15). <u>Roosting/Associated Habitat</u> • Site specific BEMP for all activities proposed within roosting areas (WDFW). • Season disturbance/noise limitations from Nov. 15-March 15. • Tree retention requirements within 250 feet of select shoreline areas.
Osprey	Occurs throughout King County, associated with riverine, marine, and open water habitats. Found in Rural and Urban Environments.	<u>Nest Site</u> • Permanent protective buffers 200 feet. May be reduced to 130 feet based on site specific management plan. • Seasonal 660 foot nest protection buffer (April 1 to October 1).

Species	Species Location	Protection Mechanisms Suggested by Literature
Red-Tailed Hawk	Documented throughout King County. Found in Rural and Urban Environments.	<u>Nest Site</u> • Permanent 325 foot buffer around nest tree. May be reduced to 275 feet under special study. • 625 foot seasonal no-construction buffer around the nest from February 1 through July 31 each year.
Vaux's Swift	Recorded in King County, potential breeding evidence throughout the county (mature/old-growth forested habitat), core habitat includes entire county. Found in Urban and Rural Environments.	• Species surveys initiated if suitable habitat occurs on parcel. • Preserve nest tree. Permanent buffer established around tree/snag if colony exists. • Preserve mature/old-growth forest or snag-rich areas on parcels (i.e., 65 % retention).
Great Blue Heron	Core habitat in western half of King County and nesting locations in western portion of King County. Found in Urban and Rural Environments.	• Permanent 1,000 foot buffer around nesting colonies. Buffer may be reduced based on a site specific management plan. • Retain mature forest vegetation in vicinity of colony to provide future nesting sites (i.e., 65% retention).
Pileated Woodpecker	Recorded throughout King County; core habitat also throughout.	• If suitable habitat occurs on the parcel, initiate surveys for the species. • Protect existing nest tree and associated stand. • In Rural, manage patches greater than or equal to 25 acres of remaining forest and woodlots widely distributed through each basin with a canopy closure greater than 70%, at least 3 trees greater than 26 inches in diameter at breast height. Also maintain smaller evenly distributed patches of forest and woodlots between 4 and 12 acres in size to serve as stepping stones and foraging habitat for woodpecker.
Purple Martin	In Northwestern portion of King County. Core habitat listed in northwest portion of King County. Mainly shown in Urban Environment.	<u>Nest Tree</u> • Historically are secondary cavity nesters but also extensively using pilings along rivers and coasts consequently protection of these is helpful. • Areas of 40-60 feet adjacent to such nest sites should remain free of human development and be cleared of shrub and tree venation. • Housing and human activities beyond 60 feet may be recommended as humans keep raptors and other predators away.
Common Loon	Recorded in central portion of King County. Small, isolated areas of habitat shown. Found in Rural Environment.	• Deter or prohibit recreational activity from known nesting and nursery sites - especially motorized watercraft. Prohibit all motorized activity and keep other watercraft and shoreline recreations further than 492ft from such sites. • Shoreline development and buildings within 1,650 feet (500m) of loon nest should be avoided and provide a permanent buffer around nest. • Prohibit unnatural lake level water fluctuations.
Spotted Owl	Confirmed breeding sites in forest production areas of King County. Possible breeding sites noted in vicinity of North Bend/Snoqualmie. Habitat identified in Rural Zone (appears to be in E, NE, SE of Snoqualmie).	• Initiate surveys in suitable habitat/areas of likely occurrence. • Permanent nest tree buffers and season buffers. • Consult Federal/State Spotted Owl recovery Plans for management suggestions.
Townsend's Big Eared Bat	Documented within south-central portion of King County. May occur throughout lowland and sub-alpine areas of King County. Found in Urban and Rural Environment.	• 100 foot buffers on hibernation sites (caves) • Gating of cave entrances. • Other hibernating roosting sites (sometimes hibernate in structures) evaluated on case by case basis and protected as appropriate.

Species	Species Location	Protection Mechanisms Suggested by Literature
Peregrine Falcons	Mainly recorded in northwest King County, near Puget sound (marine habitat). Also occurs within select areas within King County. Found in Urban and Rural Environment.	Nest Site • Limit human encroachment and disturbance of all types during breeding and early fledging. • Seasonal no-construction 1,320 foot buffer around nest site from March 1 to September 15. Restrict human access along cliff rims within 0.5 miles of nests from March 15 to July 31.
Marbled Murrelet	Documented within eastern portion of King County, appears to be associated with forest production/federal ownership. Found in Rural Environment.	Nest Site • Protect nesting stands from windthrow buffers of 300 feet wide for old growth forest stands of greater than 100 acres and 600 feet wide for less than 100 acres are recommended. • Management activities that could disturb breeding should not occur within 0.5 miles from April 1-September 15. • Where suitable habitat occurs in areas of likely occurrence, initiate species surveys and identify Murrelet Management Areas if ecologically appropriate.
Northern Goshawk	Core habitat, confirmed breeding in eastern edge of King County, forest production area/federal ownership. Found in Rural Environment.	Nest Site • At a minimum, 30 acres of the most suitable nesting habitat surrounding the nest site shall be deferred from (clear cut) harvest. The 30 acres should include known alternate nest sites and plucking posts and should be blocky or circular in shape. • A buffer with a 2,625 foot radius around active goshawk nests should be maintained free from disturbance and construction activities between March 1 and September 15. • Where suitable habitat occurs in areas of likely occurrence, initiate species surveys.
Golden Eagle	Core habitat and potential breeding sites identified in eastern half of King County, predominantly in forest production/fed ownership. Found in Rural Environment.	Nest Site Construction activities, trail use, camping below active eyries, and climbing on nest cliffs should be restricted in a 2,625- foot radius around known nest sites during the nesting period of January 15 to July 15 Roosting/Associated Habitat Seasonal disturbance/noise limitations from November 15-March 15.
Lynx	Not shown as occurring in King County.	No protection of habitat suggested at this time.
Western Gray Squirrel	No habitat or populations known in King County and no confirmed sightings identified.	Protect any pine-oak, fir-oak forests and oak/prairies from urbanization should sighting occur.
Merlin	No records, peripheral habitat shown in south east and south central King County.	• Human activities, such as development, logging, recreation, camping, hiking, or other disturbances should not occur within 1,200 feet of active merlin nests from March 15 through July 30. • Maintain at least a 300 foot no-cut buffer around known merlin nest sites when they are discovered.
Black Crowned Night Heron	No core habitat or breeding locations identified in King County.	Maintain a minimum 984 foot buffer zone from the periphery of colonies in which no human activity occurs during the courtship and nesting season (February 15 to July 31).
Western Grebe	Core habitat not shown in King County, no confirmed breeding evidence.	Deter or prohibit recreational activity from known staging and resting areas (i.e., Lake Washington) especially motorized watercraft.
Larch Mountain Salamander	Documented in the extreme southeast portion of King County. May occur in upper watershed areas, associated with talus slopes Found in Rural Environment.	• Avoid impacting talus slopes. • Buffer talus slopes with 90-150 foot protected area and leave 50% or more of additional uncut forested areas beyond buffer
Oregon Spotted Frog	One recorded location in Urban environment in King County. Species has not been documented in King County in at least 20 years.	No protection of habitat suggested at this time as no recent sightings have been made. If found utilize WDFW guidelines.

Species	Species Location	Protection Mechanisms Suggested by Literature
Fisher	Documented in King County (far east), core and peripheral habitats shown in eastern King County mostly associated with forest production.	Minimize forest fragmentation within old growth forests and the mountain hemlock zone by utilizing uneven-aged harvest techniques to reduce the percentage of stand perimeter consisting of clearcut edge.
Columbia Black-Tailed Deer	Mule deer, found throughout King County (exception is urban environment).	• Reduce habitat fragmentation/migration corridor obstructions (fences, etc.). • Establish road closures of winter range during the fall and winter months to buffer the influences of increased human disturbance. Roads on winter range open to public use should be limited to 0.5 mile of road per 1 square mile of habitat. • Development standards on deer winter range should be of the lowest that is feasible, with screening vegetation adjacent to developed lots.
Elk	Core habitat in eastern portion of King County. Found in Rural Environment.	• Reduce habitat fragmentation/migration corridor obstructions (fences, etc.). • Secure management control of critical preferred winter/spring habitat for elk through lease agreements, easements, landowner incentives, or fee purchase. • Elk calving habitat should be protected from disturbance from May 1 to June 30. Calving habitat should be provided within 1,000 feet of water on gentle slopes that contain at least 40% of the area in cover patches. Forage opening should occur as small, scattered patches. Cover patches should be at least 200 feet wide and have a canopy that exceeds 70% of trees more than 40 feet tall.
Mink	Documented in northwestern portions of King County. Habitat occurs throughout King County.	• Maintain a 75% tree, shrub, and/or persistent emergent herbaceous vegetation canopy within a 330 foot riparian buffer along streams, marshes, and shorelines (Allen 1984). • Maintain a minimum of 75% tree and/or shrub canopy closure within 330 feet of the water's or wetland's edge (Allen 1984).
Band-Tailed Pigeon	Species recorded throughout King County (Urban and Rural), core and peripheral habitats throughout King County.	• Manage forests to produce areas of dense berry producing understories and thickets of red elderberries and cascara in clear-cuts. Leave 3 trees or snags/acre in clear-cuts to serve as perch trees. • In mineral poor regions, consider providing salt-licks for pigeons containing sodium and calcium salts by bearing the mineral blocks at natural seeps. Maintain perch trees near mineral sites. • Manage patches of remaining forest and woodlots to include patches greater than or equal to 25 acres widely distributed through each basin and smaller (4-12 acre stepping stone habitat patches) distributed through the landscape.
Western Toad	Core habitat identified in eastern and western King County, predominantly outside of Urban Zone. Found in both Urban and Rural Environment.	Maintain forests adjacent to breeding ponds and wetlands.
Harlequin Duck	Recorded in King County (central portion), core habitat shown in eastern half of King County.	• Provide a 100foot (30m) buffer adjacent to nesting streams to recruit large organic debris. Also avoid logging adjacent to such streams and limit disturbance, trails and roads to at least 165 feet beyond streams. • Minimize stream hydrological changes that would influence invertebrate food supplies. • Minimize recreational disturbance during nesting and brooding from May through August.

Species	Species Location	Protection Mechanisms Suggested by Literature
Western Bluebird	Confirmed breeding evidence in north central and south central King County. Core habitat zone identified in north central portion of King County, peripheral zones in north central and south central King County. Urban and Rural Environment.	• At elevation above 600-1,000 feet, bluebirds are able to compete successfully for nesting cavities. In these regions, manage forests to retain snags and retain older, large, and partially dead trees. • Retain snags greater than 10 feet tall and 15 inches in diameter at breast height around the edges of clear-cuts (Brown 1985). Leave defective trees with heart rot, distortions, or damage as potential nest sites.
Blue Grouse	Species observations shown in eastern half of King County core habitat in eastern half of King County.	• Where blue grouse occur, use clearcuts smaller than 800 feet across and leave at least 40 trees per hectare with a minimum 9 inch diameter at breast height on wintering areas. • Use longer rotations (greater than 60 years) for wintering habitat. • Retain known winter roost areas including mature mistletoe-laden Douglas-fir thickets near ridges.
Mountain Goat	Documented within eastern portion of King County, appears to be associated with forest production/federal ownership.	• Retain conifers in an unmanaged condition 300 feet directly above and below cliffs used by mountain goats. • Maintain a one-quarter mile zone free from human disturbance around escape terrain year-round and minimize disturbance within 1 mile or escape terrain between November 1 and the end of June. • Maintain cover in travel corridor between cliffs used by mountain goats.
Wolverine	Recorded in King County, core habitat shown along eastern edge of King County/forest production/federal ownership.	• Protect large undisturbed forested and other natural areas. • Forest practices in mountain corridors between protected wilderness areas should protect and provide appropriate structures, such as large cavities, coarse woody debris, and old beaver lodges to provide den sites.
American Marten	Documented in King County (far east), core and peripheral habitats shown in eastern King County mostly associated with forest production/Federal ownership.	• Maintain forested riparian buffers of approximately 330 feet on each side of streams or terrestrial corridors at least 600 feet wide connecting patches of forest that contain suitable complex physical structure at ground level for martens). • Maintain marten habitat patches with a minimum size of 37.5 acres and average size of at least 600 acres, connected by forested riparian corridors to maintain.
Mountain Quail	Not shown to be documented within King County.	• Retain slash and/or slash piles on timber harvested sites not subject to broadcast burning. • Limit herbicides that destroy brushy habitat in clearcuts that harbor populations of mountain quail.
Van Dyke's Salamander	Currently only identified in three areas of western Washington. Not known to occur in King County.	• Protect headwater and smaller streams and adjacent buffers where salamanders are found from yarding, heavy equipment and timber harvests. Suggested buffer widths range from 90-150 feet. • Retain and/or maintain 50% shade along stream banks, seeps, wet talus and other such areas.

C. Flood Hazard Areas

What Are Flood Hazard Areas?

There are six major river systems in King County: the Skykomish, Snoqualmie, Cedar, Sammamish, Green, and White. Except for the Sammamish, each of these rivers descend from the crest of the Cascade Mountains to Puget Sound and are heavily influenced by snow and rain patterns in the mountains. In addition, dams constructed in these river systems play an important role in regulating river flow.

Flood hazard areas are regulated for the protection of people and property and are not regulated for habitat protection. However, habitat protection should be considered when designing, installing and maintaining flood protection facilities. Flood hazard areas are mapped by the Federal Emergency Management Agency (FEMA) along these major river corridors, as well as portions of their larger tributaries, such as the lower Raging and Tolt rivers on the Snoqualmie, to identify areas that are at risk from rising floodwaters. Floods occur through two natural processes: inundation and bank erosion. These processes are not mutually exclusive, and inundation can often create bank erosion, and vice versa, thus exacerbating flood hazard. Inundation occurs when floodwater and debris flow through a normally low-lying dry area, called a floodplain, when water rises above the natural containment levels in rivers, streams, or wetlands as a result of excessive rainfall or snowmelt. Bank erosion is the process whereby river and stream banks are scoured or undermined by the erosive flow of water resulting in channel migration areas. Both of these processes are natural and, at natural times, rates, and magnitudes, are important for creating and maintaining healthy aquatic and riparian habitats. This section will discuss inundation of floodplains, whereas bank erosion will be addressed separately under the Channel Migration Zones section in this paper (below).

How Do Flood Hazard Areas Function?

A floodplain is the generally flat, low-lying area adjacent to a river or stream that is periodically flooded by overbank flows during storm events. Flooding in King County is most likely to occur from October through June during periods of heavy rainfall and rapid snowmelt. During flood events, large volumes of water and debris move downstream. By definition, floodwaters are those waters that overtop the river or stream bank and flow onto the floodplain. Flooding therefore acts to provide connectivity between the river or stream and its riparian soils and vegetation. Floodplains provide storage of water during these storm events and, if properly protected or managed, can reduce local and downstream peak flood discharge and decrease flood velocity. In addition, natural floodplains provide highly productive habitat and functions for a wide variety of fish and wildlife. Many of the floodplains in King County have been altered so they no longer provide the same benefits that a natural floodplain provides. Floodplain alterations are typically caused by bank hardening and channel confinement. These alterations result in an increase in water velocity, a reduction of floodplain storage, and removal of the natural connectivity between the river or stream and the riparian vegetation, side channels, and floodplain wetlands.

How Should Flood Hazard Areas Be Protected?

Flood hazard areas are defined by mapping the relatively flat areas adjoining rivers and streams that are subject to a 1 percent or greater chance of flooding in any given year. This mapping guides the allowed uses in the mapped area in order to protect the public health and safety from flooding and to protect valuable riparian habitat for fish and wildlife. Past practices for flood control involved containing the flow of water within a defined channel by creating hard surfaces using non-erodible material. Contemporary science of floodplain management would allow floodwaters to use the entire floodplain during storm events and to allow the natural process of river systems to take place.

Traditional flood control measures include widening or deepening the channel, straightening the channel, levee construction adjacent to the channel, stream bank stabilization, and clearing living and dead vegetation in and along the river. Levees increase flow capacity of the channel, and increased flow capacity results in higher water velocity and depth, both of which may be harmful to fish. However, studies have shown that over time levees function as bank stabilization and help reduce the erosional forces of the water. Clearing rivers and streams of vegetation and large woody debris increases the capacity to convey floodwaters but may increase bank erosion. In addition, the removal of large woody debris affects the ability for the stream or river to form pools, which are important salmonid habitat. The introduction of large woody debris does not significantly decrease the flood-carrying capacity of the stream or river. The removal of vegetation from within streams and rivers also reduces the ability to trap and store sediment and nutrients important for aquatic life.

Channelized rivers tend to have (1) increased and greater fluctuations in water temperature, (2) reduced cover and diverse habitat for fish, and (3) less organic matter input. These impacts result from traditional flood control techniques. Contemporary flood control measures use alternative construction and design practices to mitigate impacts. These measures are summarized in Table 7 below.

Table 7. Contemporary Flood Control Measures Summarized By Bolton (2000)

Minimization of Impacts during Design and Construction
emulate nature
revegetate or maintain vegetation
minimal channel alteration
use riprap judiciously
random placement of rocks
two-stage channel for flood control
Preservation of Channel Morphologic Features
preserve original meander bends
preserve small channel features, such as pools and riffles
reconstruct only one half of a channel and leave the other side untouched
alternate reconstruction segments on opposites of the channel
Vegetation Incorporation Into Levees, Revetments and Other Embankments
use a variety of vegetation to create habitat complexity
create a vegetated berm for two-stage channel morphology
set back the levee from the active low-level channel to allow natural revegetation
Integrated Stream Bank Protection
engineered large woody debris
Active Restoration and Rehabilitation Techniques
complete levee and revetment removal
habitat restoration
Partial Restoration, Channel Geometry and Habitat Features
partial meander restoration
restore to more natural cross-section morphology
restore to two-stage channel morphology
restore pool-riffle sequence
Holistic Riparian Corridor Management
changes in public attitude
zoning
delineation and mapping of 200+ year floodplains
conservation easements
land purchases

D. Channel Migration Zones

What Are Channel Migration Zones?

Channel migration is the process of a river channel moving, or migrating, laterally across its floodplain. Channel migration occurs as a river erodes one bank and deposits sediment along the other; these actions result in a net migration of the channel through time. Although channel migration by bank erosion may occur gradually, a channel can migrate great distances over timeframes of decades or centuries. Channel migration also can occur as an abrupt shift of the channel to a new location; this abrupt shift is called an avulsion. An avulsion may happen during a single flood event, such as when a logjam re-routes the river into a side channel during high flows. The highest rates of channel migration occur in zones of rapid sediment deposition, such as where steep rivers flow out of foothills onto flatter floodplains. Areas affected by channel migration are called Channel Migration Zones (CMZs).

How Do Channel Migration Zones Function?

At the watershed scale, a CMZ can be thought of as a corridor of variable width along the present river channel. Within this corridor, water, sediment, and organic material are transferred through river and floodplain and routed from headwaters to mouth on time scales of days to decades. Because of the dynamic nature of such fluxes and routings, channel migration can pose a threat to public safety. CMZs are classified as a type of flood hazard area; the hazard to people and structures results from bank erosion or outright channel relocation rather than getting inundated by overbank flow. A CMZ and its associated flood hazard can extend beyond the 100-year floodplain (described above).

Despite the potential threat to humans and property, the dynamic fluxes and routings within a CMZ can benefit habitat for many species of fish and wildlife, especially salmon. The flux of gravel and large woody debris to the river resulting from channel migration illustrates the connectivity between a river and its floodplain. The overall channel morphology within a CMZ often includes accessible side channels and/or multiple channels, both of which increase channel complexity and benefit salmonid spawning and rearing habitat.

Bank erosion from both gradual and abrupt channel migration recruits spawning gravel from alluvial riverbanks. With bank erosion, trees often topple into the channel and become a source of large woody debris, which creates high quality, diverse habitat for salmon rearing, spawning, migration, and refuge purposes.

How Should Channel Migration Zones Be Protected?

CMZs are protected, whether for public safety or habitat conservation purposes, by delineating the outer boundaries of channel migration and regulating land use within those boundaries. There are often obvious physical features in the floodplain that indicate channel migration has occurred, such as progressive erosion and deposition at meander bends or side channels and oxbow lakes. However, the extent of a CMZ may not be physically identifiable on the ground, depending upon the time scale used to define the CMZ.

Generally, a CMZ is the corridor that includes the present river channel plus the adjacent area through which the channel has migrated or is likely to migrate within a given timeframe. The extent of channel migration will vary depending on the timeframe of interest. If the timeframe were to include the period since the last glaciation some 14,000 years ago, then the CMZ would likely encompass the entire valley bottom. However, the period of time used to define a CMZ is often 100 years because available information can be used to evaluate channel movement in this time frame. Also, it is believed that this time span is sufficient to grow mature trees that can provide functional large woody debris to most channels.

To understand and map the potential full extent of risk to people and fish and wildlife habitat, King County staff assesses historic channel locations, geology, basin hydrology, riverbank materials, current channel conditions, abandoned channels and potential avulsion sites, channel migration rates, and existing infrastructure. As of November 2002, King County has studied and mapped CMZs along selected portions of four major rivers: the Tolt River, River Mile (RM) 1.7 to RM 6; the Three Forks of the Snoqualmie River, including the lower South, Middle, and North Forks; the Raging River, RM 1.5 to RM 9; and the middle Green River RM 25 to RM 46. Study findings were used to map severe channel migration hazard areas and moderate channel migration hazard areas within the CMZ. Mapping of CMZs will occur along other major rivers of King County in the near future.

E. Geologic Hazard Areas

Geologic Hazard Areas are defined by the Growth Management Act to include erosion hazard areas, seismic hazard areas, landslide hazard areas, coal mine hazard areas, and volcanic hazard areas. Each hazard area is addressed separately below.

Erosion Hazard Areas

What Are Erosion Hazard Areas?

Erosion Hazard Areas were mapped by King County as part of the original Sensitive Areas Ordinance in the late 1980s. Erosion Hazard Areas were mapped based on the grain size of the various soil units found in King County. In general, the finer-grained the soil, the more erosive it is. Geologists that did the original mapping also took slope, or gradient, into account as they assessed the likelihood of excessive erosion—the steeper the slope, the more likely was excessive erosion to occur because of higher runoff energy. As with all geologically hazardous areas, there are numerous variables at work including grain-size, slope gradient, rainfall frequency and intensity, surface composition and permeability, and type of cover (e.g., pavement or forest). These elements, when combined, dictate the overall susceptibility of a slope to erosion.

How Do Erosion Hazard Areas Function?

In general, rainfall or accidental surface-water discharges begin the erosion cycle. Individual raindrops impacting a disturbed or denuded surface cause soil particles of sand and silt size to break away from the surface and move downslope. As water accumulates on the surface, it tends to concentrate in small channels that develop as the soil particles are moved or mobilized. As water accumulates in the small channels, it gains volume and energy and is able to mobilize ever larger particles. In this way, erosion features develop on a surface—they start as very small channels, or rills, and tend to grow in size to large gullies and canyons over time. Material that is caught up in this process is carried downslope until the gradient flattens out and the energy of the water is reduced. When the energy drops below a certain threshold, the particles, or bedload, drop out of the water. This deposition of bedload generally occurs either on land in floodplains or within waterbodies like lakes or Puget Sound. Very fine particles of certain clay minerals, once mobilized, can take days or even years to drop out of suspension in the water.

Human-induced erosion can be very damaging to water quality in adjacent water bodies—waters that often support salmonid fish and other species. Silt and sand-sized particles are particularly damaging to the stream environment if excessive deposition occurs. The silt and sand can bury and asphyxiate fish eggs that are deposited in gravel, can fill the spaces between gravel that support aquatic insects, and can even kill fish by damaging or clogging gill structure.

How Should Erosion Hazard Areas Be Protected?

It should be understood that some erosion is natural and is in fact very important to the overall health of a stream system. The difficulty is in determining how much erosion is too much. Natural erosion and landsliding processes should be allowed to occur to provide the sand, gravel, cobbles, and boulders that streams need to remain productive.

By promoting sound development practices including the use of Best Management Practices (BMPs) that limit erosion and sedimentation during construction, the amount of excess sediment that reaches stream systems can be limited. BMPs that are commonly employed include covering bare ground with straw and/or plastic sheeting, using silt fences, and by planting denuded areas as soon as possible after development.

Seismic Hazard Areas

What Are Seismic Hazard Areas?

King County lies in the Puget Sound Lowland, an area that is subject to daily earthquake activity—though most is not detectable—and is historically subject to very large earthquakes. The most recent large earthquake was the February 28, 2001, Nisqually Earthquake. This earthquake created a great deal of damage and minimal loss of life. Seismic Hazard Areas are those areas within King County that are subject to severe risk of earthquake damage as a result of seismically induced settlement or soil liquifaction. Severe risk of damage is loosely defined as the potential for damage that is structural rather than cosmetic in nature.

Seismic Hazard Areas were mapped by King County geologists beginning in the 1970s and continuing on through publication of the Sensitive Areas Map Folio in December 1990. In general, Seismic Hazard Areas are found in floodplains like the Snoqualmie Valley and the Green River Valley, and to a lesser extent in sloping areas and bluffs adjacent to the floodplains and Puget Sound.

How Do Seismic Hazard Areas Function?

Seismically induced settlement is an immediate physical lowering or consolidating of the ground surface that occurs in loose, native sedimentary soils or in fill that has not been well compacted. This type of settlement can also occur near or on slopes that are relatively stable under normal circumstances but that lose lateral stability under seismic loading. Settlement of the soil surface causes damage to lifelines/utilities, roads, and foundations—damage that can be catastrophic.

Soil liquifaction is a relatively rare phenomenon that occurs in areas underlain by loose and saturated soil of a fairly narrow grain-size. In King County, liquifaction typically occurs in the sediments that underlie floodplain areas. When liquifaction occurs, pore water pressure between the individual soil particles temporarily increases because of seismically induced shaking and forces the grains apart, an action that causes them to lose all shear-strength. The soil mass then behaves like a viscous fluid instead of a solid. It can flow laterally or geyser up above the surrounding surface leading to damage or destruction of overlying and adjacent structures. Damage is usually due to loss of support within the soil mass. Liquifaction can also occur in certain types of sensitive clay minerals, but those soil types are very rare or non-existent in King County.

How Should Seismic Hazard Areas Be Protected?

Seismic activity is a fact of life in the greater Puget Sound area. Inadequate geotechnical study and engineering ultimately lead to unsafe building practices and unsafe structures. Requiring rigorous study and design standards and careful regulation and monitoring of construction practices leads to safer dwellings, roads, and buildings.

<u>Landslide Hazard Areas</u>

What Are Landslide Hazard Areas?

Landslide hazard areas are areas that exhibit rapid movements of sliding soil and rocks and are separated from the underlying stationary part of the slope by a definite plane of separation. Sliding often includes slow, long-term, and plastic deformation of slopes and usually occurs not along one distinct failure surface, but within a system of sliding planes. This movement is often referred to as creep.

Many of King County's major valleys and shoreline bluffs are underlain by steeply sloping glacial deposits that are highly susceptible to landslides. These unstable slopes can be very hazardous to people and structures. The identification of areas that are susceptible to landsliding is necessary to provide guidance when designing and constructing structures or clearing and grading. In 1990, King County published the King County Sensitive Areas Map Folio. The folio includes information relating to landsliding in the Puget Sound area.

How Do Landslide Hazard Areas Function?

Sliding phenomena involve such a variety of processes and contributing factors that classification is very complex. Many classification systems have been proposed over the years. In general terms, a landslide is movement downslope of a mass of soil, rock or both and water (usually.) The downslope movement may be very swift or may be very slow depending on the type of material involved, volume of water, slope gradient, and a host of other variables. The mass of material may be shallow or surficial in nature and small, or it may extend very deep underground or be deep-seated and huge in size. Some actively moving landslides in King County exceed 2 million cubic yards in volume.

Landslides in King County occur in sloping areas that are underlain by interbedded sediments that vary in grain size. For instance, a typical landslide along the Puget Sound bluffs will occur in sands and silty sands that are deposited over a relatively impermeable silt/silty clay layer. Water from precipitation percolates down through the more permeable sands and silty sands until it hits the silt/silty clay layer. The water then flows laterally along the impermeable layer until it reaches the sloping surface, or daylights. Oftentimes the water cannot move as fast laterally as it is being deposited by precipitation from above and the water builds up in the soil layer. As the water builds up, pressure increases between the individual soil particles, and the soil mass as a whole begins to lose shear strength. At some point, the loss of shear strength allows particles that were formerly locked together to start sliding past one another under the influence of gravity.

Depending on a variety of factors including the slope or gradient of the soil layers, the amount of water and rate of deposition, and the type of material involved, the rate of movement may be very slow (creep) or very fast. In either case, the soil mass can and does cause catastrophic damage to structures that lie above it or that lie in its path. Landslides that move relatively swiftly may strike structures before they can be evacuated, and injuries or fatalities can occur. Landslides can also be triggered when there is a loss of lateral support at the bottom, or toe, of a slope due to the action of water, either in a stream or river or because of wave action. As the toe is eaten away, support for the overlying soil mass deteriorates and eventually gravity causes the slope to collapse. This type of slope failure is usually quite rapid once initiated and for that reason can be very hazardous.

How Should Landslide Hazard Areas Be Protected?

Buffers should be established around the perimeter of mapped Landslide Hazard Areas. Development that is proposed within those buffers or within the slide area itself must meet scientifically based, rigorous design and construction standards. Because of the extreme variability that is exhibited by areas that are subject to landsliding, site-specific studies must be prepared in order to design, construct, and safely occupy a structure that is to be built in one.

Current practice dictates that in order to build in a Landslide Hazard Area, a person must first retain the services of a geotechnical engineer or engineering geologist. The engineer or geologist will perform subsurface exploration in the area, collect samples, and test those samples in a laboratory. The results of the exploration and testing combined with local expertise will aid the designer in developing a proposal that includes site-specific design elements for the foundation and drainage systems. He or she will also provide a detailed construction sequence and monitoring plan. That proposal will be submitted in report form to the permitting agency for review and approval. If the proposal is approved, the buffer around the landslide may be reduced to allow for construction adjacent to the hazard area. In most cases, a foundation and drainage design can be developed that will allow for development in the buffer of the landslide hazard area that will remain stable during and after construction

Coal Mine Hazard Areas

What Are Coal Mine Hazard Areas?

A coal mine hazard area is an area underlain by abandoned coal mine workings including adits (a nearly horizontal mine entrance shaft,) drifts (secondary passages between main shafts,) tunnels, or air shafts (often nearly vertical). In King County, coal was first mined in underground workings in the Renton area in 1854. Underground mining continued in King County until about 1970. It is estimated that approximately 50,000 acres are underlain by underground mines in western Washington. Virtually all coal mines that are still producing today are surface mines. Underground coal mine workings present a number of hazards that can affect people, lifelines and structures.

Coal mine hazard areas were mapped by King County using detailed coal mine maps prepared by mining companies for annual submittal to the State. The Washington State Department of Natural Resources, Division of Geology and Earth Resources is responsible for the regulation of mining in the State. Not all mine workings will appear on the available maps, either because the mines were worked prior to 1900 or because they were small and unregistered by the State.

How Do Coal Mine Hazard Areas Function?

Abandoned subsurface mines leave large voids that can collapse and generate sinkholes in the surface above. This phenomena is known as subsidence. Cave-ins can and do occur in the mines that can lead to surficial damage, and noxious gas and dead air (little or no oxygen) can collect in the workings. Unstable mine openings and spoil piles can slide or fail unpredictably.

It has long been recognized that subsidence creates a larger surficial feature than the actual size of the mined out area that has collapsed. For this reason, it is common to apply an angle of draw to the edges of the mine for estimating the potential area of subsidence. This angle is typically 25-35 degrees measured from the vertical. Use of the angle of draw is described below.

How Should Coal Mine Hazard Areas Be Protected?

Coal mine hazard areas should be identified using existing maps and special studies. Hazard areas should have protection boundaries applied to them, such as buffers. The boundaries should be established based on the known physical dimensions of the coal mine and on the stratigraphy of the beds in the area. For example, where mines lie in nearly horizontal beds, a 35 degree angle of draw is applied from the outermost edge of the workings and then a 200-foot safety zone is added. Thus, the size of the boundary is directly related to the depth of the mine. The methodology varies somewhat depending on the underlying beds and on the surface (i.e., sloping vs. horizontal).

In general, special studies can be used to determine whether coal mines exist in an area, and then design criteria for foundations and drainage systems can be applied. Repair work to ameliorate damage due to subsidence events should fill or block adits and airshafts as they are discovered.

Volcanic Hazard Areas

What Are Volcanic Hazard Areas?

Volcanic hazard areas are zones considered to be dangerous to public health and safety around an active volcano. In the Pacific Northwest, the presence of a series of subduction zones or stratovolcanoes presents a unique and very dangerous hazard to local populations and infrastructure. Volcanoes of this type, including Mt. St. Helens and Mt. Rainier, can erupt in a violent fashion and deposit enormous amounts of material onto the landscape. These deposits occur in a number of different ways, all of which pose hazards to humans and the environment. These areas generally pose hazards only during and immediately after volcanic eruptions.

How Do Volcanic Hazard Areas Function?

In King County, widespread damage is most likely to come from an eruption on Mt. Rainier. It is less likely, though possible, that damage from ashfall and acidic aerosols could result from an eruption on one of the other subduction zone volcanoes found along the West Coast of the United States. In general, the major hazardous geological processes associated with the eruption of a volcano like Mt. Rainier are as follows:

Tephra Fall. During explosive eruptions, a mixture of hot volcanic gases and tephra, which includes volcanic ash and larger fragments is ejected rapidly into the air from volcanic vents. The finer fraction of the tephra is commonly less dense than the air and rises into the air until no longer buoyant. In the case of the 1980 eruption of Mt. St. Helens, the ash column rose about 15 miles in less than 30 minutes. As the energy to keep them suspended diminishes, the particles begin to fall under the influence of gravity. Larger particles fall out first and nearer the volcano while sand-sized and finer particles may fall out many hundreds of miles away. The tephra forms a blanket-like deposit that is thicker near the volcano and thinner and finer with increasing distance from the vent. The major hazards associated with tephra fall are (1) impact of falling fragments, (2) suspension of abrasive fine particles in the air and water, and (3) burial of structures, lifelines, and vegetation.

Pyroclastic Flows. Pyroclastic flows are avalanches of hot (300-800C,) dry, volcanic rock fragments and gases that descend a volcano's flanks at speeds ranging from 20 to more than 200 miles per hour (10-100 meters/second) Because of their mass, high temperature, high speed and great mobility, these flows are destructive and pose lethal hazard from incineration, asphyxiation, burial, and impact. Because of their high speed, pyroclastic flows are difficult or impossible to escape. Evacuation must take place before such events occur. These flows have been known to move many miles downslope from the volcano. They typically concentrate in valleys and move rapidly out into adjacent areas.

Lahars. A lahar is a mixture of water, ice and sediment that is generated during and sometimes after an eruption. Hot gases and magma that are ejected under and on top of snow and ice fields rapidly melt the snow and ice creating a mix of tephra, sediments and solidified lava that flow very rapidly down the flanks of the volcano. Lahars are gravity-controlled flows that are channeled into valleys as they move downhill. Lahars triggered during the 1980 eruption of Mt. St. Helens were 10-50 feet deep and traveled at speeds of 45-90 mph (20-40 m/sec) down the mountain's flanks. Upon reaching flatter river valleys, they slowed down to 22-45 mph (10-20 m/sec). Lahars typically grow in size as they move downslope by picking up sediment, water and organic materials (such as trees) through a process called bulking. Volume commonly increases by a factor of 3-5. As lahars get farther away from their source, they slow down and flatten out destroying structures and lifelines in their path.

Lateral Blast. A lateral blast is a volcanic explosion that has a significant low-angle component and is typically confined to less than 180 degrees of circumference. Lateral blasts can generate significant pyroclastic flows and can launch large particles or ballistic projectiles many miles from the mountain. Mt. St. Helens erupted with a massive landslide that collapsed the magma body and attendant hydrothermal system within the mountain. This collapse resulted in a huge lateral blast that knocked over trees and structures for many hundreds of square miles around the north side of the mountain.

Lava Flow. Lava that emanates from mountains such as Mt. Rainier and Mt. St. Helens is typically quite viscous and does not usually flow far from the vent. Rather, it forms very steep-sided domes atop the mountain that lead to dome collapse, explosive eruption, pyroclastic flows, and lahars. Lava flows like those seen in shield volcanoes (e.g., Mauna Loa in Hawai'i) do not usually occur in Cascade volcanoes, but there is evidence that fluid basaltic flows have emanated from Mt. St. Helens in the past.

How Should Volcanic Hazard Areas Be Protected?

Past experience and present practice indicate that the best way to regulate volcanic hazards is by zonation. Roughly circular zones that represent decreasing risk with distance from the mountain are established based on the geologic record of past eruptive events as mapped by geologists. Each zone is mapped based on the probability of occurrence of the various hazards. So-called flowage hazards (pyroclastic flows, lahars, and lateral blasts) are the most deadly and damaging and are typically mapped in three zones: (1) a proximal zone of high concentration or high density flow, (2) a proximal zone of low concentration or low density flow, and (3) a distal zone where well-channelized lahars represent the only significant hazard. Zones 1 and 2 are subject to the full gamut of hazards as discussed above and should be regulated with the understanding that these events occur with such rapidity that it is impossible to evacuate after an eruption has begun. Evacuation must happen before an eruption. Zone 3 is different in that regulation can be limited to those areas where lahars are expected to descend. That regulation could take the form of buffers around historical lahar deposits or could be a more generalized based on topographic elevation.

3. Best Available Science Working Reference List

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